

**A COMPARATIVE STUDY OF DIFFERENT GAS CHANNEL  
STRUCTURES IN PERFORMANCE DEGRADATION OF PROTON  
EXCHANGE MEMBRANE FUEL CELL**

**Abhilasha Singh\***; **Prateek Arora\*\***; **Kripa Shanker Singh\*\*\***;  
**BP Singh\*\*\*\***; **Purushottam Kumar\*\*\*\*\***

\*Department of Physics,  
Raja BalwantSingh College,  
Dr. Bhimrao Ambedkar University,  
Paliwal Park Agra, INDIA  
Email id: abhilasha.bah@gmail.com

\*\*Department of Physics,  
IBS Khandari Campus,  
Dr. Bhimrao Ambedkar University,  
Paliwal Park Agra, INDIA

**DOI: 10.5958/2249-7137.2026.00002.7**

---

**ABSTRACT**

*The electrochemical performance and durability of proton exchange membrane fuel cells (PEMFCs) are strongly governed by the geometry and topology of the reactant flow field. In particular, the gas channel configuration plays a critical role in regulating reactant distribution, water management, pressure drop and interfacial mass transport between the gas diffusion layer (GDL) and the catalyst layer. PEMFCs generally exhibit enhanced current density and improved polarization characteristics when a larger fraction of the gas flow channel area is in direct contact with the GDL, thereby promoting more uniform reactant utilization and reduced concentration overpotentials. In the present study, a comparative numerical investigation of different gas channel structures and their influence on PEMFC performance degradation was conducted using COMSOL Multiphysics. Two alternative gas flow channel geometries with identical inlet and outlet cross-sectional areas but differing channel–GDL contact areas were developed and analyzed. A conventional rectangular (cuboidal) parallel flow field and a cylindrical parallel flow field design were selected to systematically assess the impact of channel geometry on electrochemical and transport phenomena. We investigated and observed the hydrogen mass fraction, ionic potential and electronic potential include the oxygen, nitrogen, water mass fractions and the current density across the membrane. The velocity field vectors and the pressure in the anode and cathode compartments is also studied. For a rectangular (cuboidal) structure, it displays better results for pressure, velocity and membrane current density.*

**KEYWORDS:** *Topology, Cylindrical Channel, Rectangular (Cuboidal) Channel, Ionic Density, Boundary, Pressure, PEMFC.*

---

**REFERENCES**

1. Liu Z. Fuel cell performance. New York: Nova Science Publishers, p.284 (2012).
2. A. J. Appleby. From Sir William Grove to today: Fuel cells and the future. *Journal of Power Sources*, **29**, 3 (1990).
3. Hoogers G.; *Fuel Cell Technology Handbook*, CRC Press. 332 (2002).
4. R. Mark Ormerod. Solid oxide fuel cells: *Chem. Soc. Rev.*, **32**, 17 (2003).
5. Grime P.; *IEEE Aerospace and Electronic Systems Magazine* **15** (2) 41 (2000).
6. Mond L., Langer C.; A new form of gas battery, *Proceeding Royal Society London* **46**, 296 (1889).
7. Hoogers G. *Fuel cell technology handbook*. Boca Raton, FL; London: CRC Press. 1 v. (various pagings) [16] p. of plates, (2003).
8. Wang Y, Chen KS and Cho SC. *PEM fuel cells: thermal and water management fundamentals*. New York: Momentum Press, (2013).
9. Segura F, Andujar JM, Duran E, *Analog Current Control Techniques for Power Control in PEM Fuel-Cell Hybrid Systems: A Critical Review and a Practical Application*, *IEEE Trans. Ind. Electron.* **58**, 1171 (2011).
10. Jia J, Wang G, Cham YT, Wang Y, Han M, *Electrical Characteristic Study of a Hybrid PEMFC and Ultracapacitor System*, *IEEE Trans. Ind. Electron.* **57**: 1945 (2010).
11. Nguyen T V, *Water management by material design and engineering for PEM fuel cells*, *ECS Trans.* **3**, 1171 (2006).
12. Abtahi H, Zilouchian A, Saengrung A, *Water Management of PEM fuel cells using fuzzy logic controller system*, 2005 *IEEE International Conference on Systems, Man and Cybernetics-SMC*, Waikoloa, USA, 3486, (2005).
13. Petrone G, Cammarata G, *Modelling and Simulation*, Croatia: InTeach Education and Publishing; p. 677 (2008).
14. Liu Z. Fuel cell performance. New York: Nova Science Publishers, 2012, p.284.
15. Viorel Ionescu, *Simulating the Effect of Gas Channel Geometry on PEM Fuel Cell Performance by Finite Element Method*, *Procedia Technology* **22**, 713 (2016).
16. Zhang J, Xie X, Tang Y, Song C, Navessin T, Shi Z, Song D, Wang H, Wilkinson DP, Liu Z. S, Holdcroft S, *High temperature PEM fuel cells*, *J. Power Sources* **160**: 872 (2006).
17. Ionescu V, *Simulating the effect of gas channel geometry on PEM fuel cell performance by finite element method*, *Procedia Technology*; **22** (2016).
18. Kone J P, Zhang X, Yan Y, Hu G and Ahmadi G, *Three-dimensional multiphase flow computational fluid dynamics models for proton exchange membrane fuel cell: A theoretical development*, *The Journal of Computational Multiphase Flows* **9** (1) 3 (2017).
19. Schmidt T. J. and Baurmeister J., *Properties of high-temperature PEFC Celtec®-1000 MEAs in start/stop operation mode*, *J. Power Sources*, **176**, 428 (2008).

20. Zhang J., Tang Y., Song C., and Zhang J., Polybenzimidazole-membrane-based PEM fuel cell in the temperature range of 120–200 °C, *J. Power Sources*, **172**, 163 (2007).
21. Weng D., Wainright J. S., Landau U., and Savinell R. F.; Electro-osmotic Drag Coefficient of Water and Methanol in Polymer Electrolytes at Elevated Temperatures *J. Electrochem. Soc.*, **143**, 1260 (1996).
22. Ren X., Henderson W. and Gottesfeld S., Electro-osmotic Drag of Water in Ionomeric Membranes: New Measurements Employing a Direct Methanol Fuel Cell, *J. Electrochem. Soc.*, **144**, L267 (1997).
23. Incropera F. P., DeWitt D. P., *Fundamentals of Heat and Mass Transfer*, John Wiley & Sons, New York 1996.
24. Ionescu V. High temperature PEM fuel cell steady-state transport modeling. *Ovidius University Annals of Chemistry* **24** (1), 55 (2013).
25. T. Zhang et al. Combination effects of flow field structure and assembly force on performance of high temperature proton exchange membrane fuel cells. *Int J Energy Res.* **45**, 7903 (2021).